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Entomology

THE WHEAT STRAWWORM.

(*Isosoma grande* Riley.)

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The wheat strawworm (fig. 1) sustains about the same relations to winter-wheat culture west of the Mississippi River that the joint worm (*Isosoma tritici* Fitch)[b] does to the cultivation of this cereal east of this river. Both, when excessively abundant, occasion losses varying from slight to total. A wheat stem attacked by the jointworm may produce grain of a more or less inferior quality and less of it; but the spring attack of the wheat strawworm (fig. 5) is fatal to the plant affected, as no grain at all is produced; and while the second generation of the same has a less disastrous effect in the field, it nevertheless reduces the grade and weight of the grain.

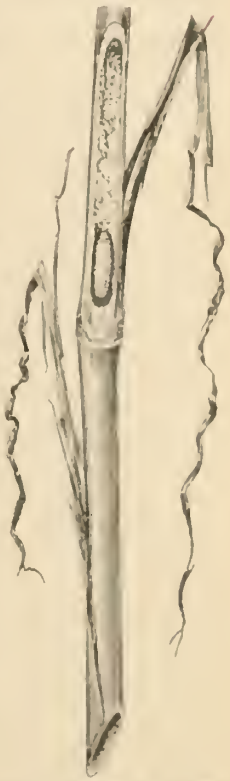

FIG. 1.—Larva of *Isosoma grande* in wheat straw. Original.

In the Ohio Valley and south of Pennsylvania the ranges of these two insects overlap (fig. 2); both species are often to be found in the same field, the wheat strawworm, however, being less abundant and doing usually but slight injury, while the jointworm occasionally becomes a serious pest.

[a] During the last two years Mr Reeves has been engaged in the investigation of this pest in the State of Washington in cooperation with the agricultural experiment station of that State. With the exception of the statements made relative to the behavior of the pest in the Northwest, for which exclusive credit is to be given the junior author, the senior author is responsible for the circular.

[b] See Circular No. 66, Bureau of Entomology, United States Department of Agriculture, 1905.

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U S DEPOSITORY

West of the Mississippi River, throughout the winter-wheat growing territory, the jointworm, if it occurs at all, is never destructive. The wheat strawworm, on the other hand, appears to be generally distributed, at times committing very serious depredations which have, at least in some cases, been charged to the Hessian fly, as shown by the fact that some of these ravages have occurred in sections where the Hessian fly is not known to exist. Besides, while the Hessian fly is manageable with more or less difficulty, the wheat strawworm is

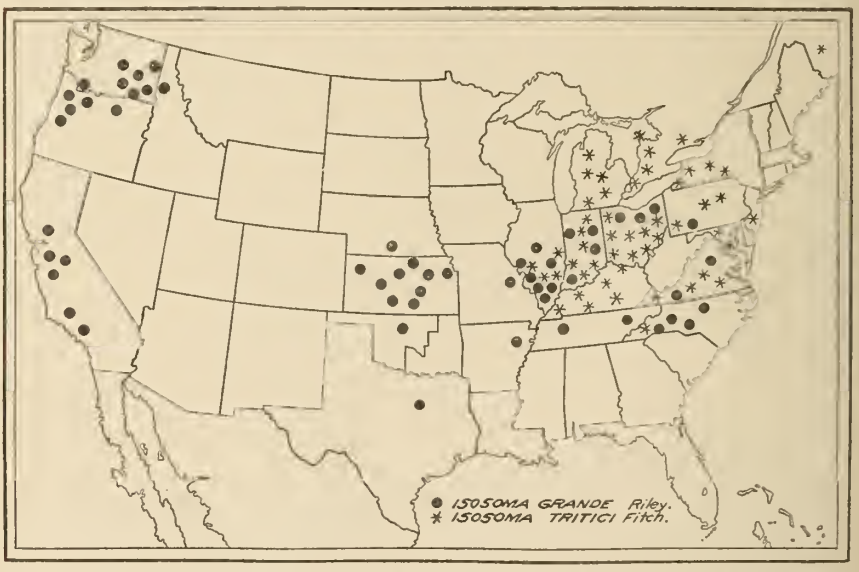

FIG. 2.—Present known distribution of *Isosoma grande* and *Isosoma tritici* in the United States. (Original.)

one of the easiest of all insect pests to control by entirely practical measures. Indeed, it need not be allowed to become a pest at all.

DESCRIPTIONS AND SEASONAL DEVELOPMENT.

There are two generations of the insect annually, the adults of the first generation (fig. 3) differing considerably in appearance from those of the second (fig. 4). To the farmer they will all look like minute or large, shining black ants, with or without wings, their legs more or less banded with yellow, and having red eyes. Individuals of the first generation emerge in April from the outstanding straws and stubble. They are very small, most of them are females, and many are wingless. The females deposit their eggs in the young wheat plants, the stems of which at this time extend but little above the surface of the ground. The egg is placed in or just below the embryonic wheat head (see fig. 6) and the larva or worm works within the

stem, usually causing a slight enlargement. When the worm is full-grown it will be found in the crown of the plant, having eaten out and totally destroyed the embryonic head, its body occupying the cavity thus formed.

Fig. 3.—Wingless adult of the spring form of *Isosoma grande*. (Original.)

The females (fig. 3) which deposit these eggs, being small and frequently wingless, are in no way fitted for traveling long distances. The larva or worm (fig. 1) is of a very light straw color, indeed almost white, with brown jaws, the form of the body being as shown in the illustration. These worms develop very rapidly and, as they feed on the most nutritious part of the plant, they become robust and larger than those found in the mature straw in late summer. In May the larvæ become full grown (fig. 5) and pass at once through a short pupal stage. (See fig. 7.) The pupæ are at first the same color as the larvæ, but later change to a shining jet black. In a few days the fully developed insects gnaw circular holes through the walls of the stem and make their way out. These adults (fig. 4) are much larger and more robust than the individuals of

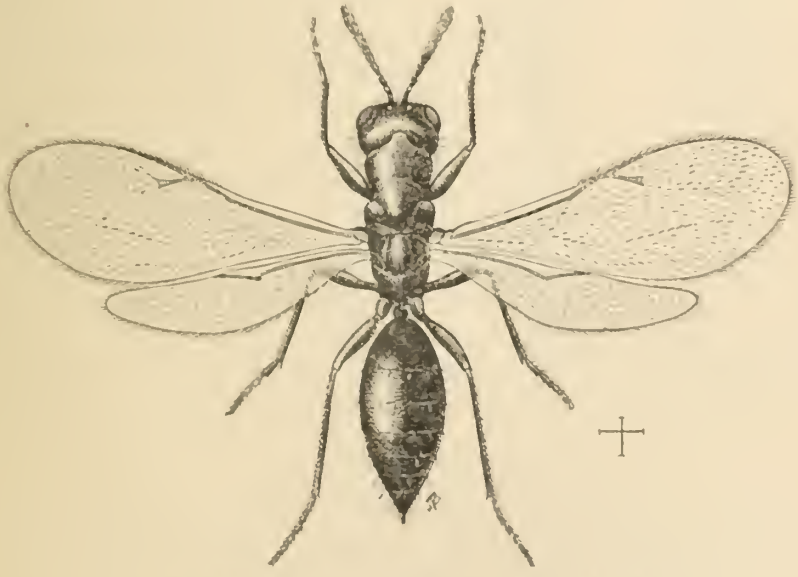

Fig. 4.—*Isosoma grande*. Adult female, summer form. (Original.)

the first generation and are provided with fully developed, serviceable wings. That they make good use of their wings, and scatter themselves about over fields adjacent to their place of development, is

shown by their occurrence in fields of grasses (in the stems of which they do not breed) situated considerable distances from wheat fields. In ovipositing, the females of this generation select the largest and most vigorous-growing stems in which to place their eggs.

The adults of the second generation deposit their eggs from early May, in Texas, up to the middle of June, in northern Indiana, or about the time the wheat is heading. Their aim at this time is to place the eggs singly in the growing stem just above the youngest and most succulent joints, which are not so covered by the enfolding leaf sheaths as to be inaccessible to them (see fig. 8). Thus it is that the stage of advancement in the growth of the wheat stems at the time of oviposition of the summer generation of females determines whether the larvæ will be well upward in the straw, and therefore removed after harvest, or lower down and consequently left in the field in the stubble.

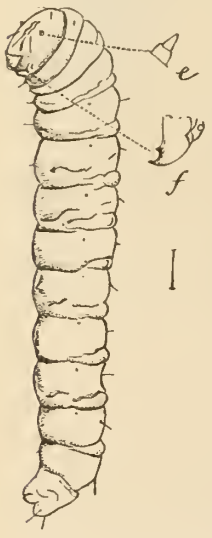

FIG. 5.—Larva of the wheat strawworm (*Isosoma grande*): *e*, Antenna; *f*, jaw. Line at right indicates natural length. (After Riley.)

The method of oviposition and the point where the egg is usually inserted are shown in figure 8. The shape of the egg after being placed in the stem is also shown in the same figure. The larva forms no gall, nor does it harden the stem within which it develops. There is normally but one larva in each joint; but if several eggs have been placed between joints and produce larvæ there will be one in the center of the stem just above the joint and others in the walls just under the internal wall covering or inner epidermis. These larvæ in the walls of the straw do not, as a rule, kill the stem, but their effect is to shrink kernels, curtailing the yield by reducing the weight. The larvæ develop rapidly and reach their full growth before the straw has hardened. By October, in the Middle West, though earlier in the South, they pass into the pupal stage, in which, as a rule, they remain until early spring, whereupon they develop to adults and gnaw their way out.

HISTORY OF THE SPECIES.

In June, 1880, Mr. J. K. P. Wallace, of Andersonville, Tenn., sent wheat straws containing larvæ of this species to Dr. C. V. Riley, then Government Entomologist, with the statement that nearly every straw in his field was infested by similar larvæ and as a consequence was inclined to fall before the grain had fully ripened. It was from these straws that the types of *Isosoma tritici* Riley were secured. In October, and later on in 1881, Mr. J. G. Barlow, of Cadet, Mo., sent

Doctor Riley many infested straws, from which adults of the spring form were afterwards reared. At Carbondale, Ill., in June, 1882, Prof. G. H. French found the species infesting wheat fields, in some cases 93 per cent of the straws being affected and from one to three larvæ being found in each straw.[a]

September 16, 1882, straws containing pupæ and an occasional larva were received by Doctor Riley from Mr. J. A. Starner, Dayton, Columbia County, Wash. On October 1, 1883, the senior author received infested straws from Stockton, Cal., through Professor French, and from these he was able to rear the spring form of adults during the following February. On May 8, 1884, he found adults abroad in a wheat field near Bloomington, Ill. On May 9 oviposition was observed, larvæ were found in the wheat plants May 28, and a single pupa was found on the following day, all in the same field of growing wheat. Straw taken from this same field early in the following July produced the spring form of this species the following spring—April, 1885.

FIG. 6.—*Isosoma grande*. Showing point where female of the spring form deposits the egg in young wheat in early spring. Enlarged, showing position of egg, at right. (Original.)

At Oxford, Ind., June 6, 1884, the senior author found large winged adults of the summer form ovipositing in the stems of growing wheat, and in a small developed stem like those observed in May, about Bloomington, Ill., a living pupa was found. Straws from the Oxford field gave precisely the same form the following April as did the straw from Bloomington. The larger form, observed at Oxford June 6 and later, was also collected in fields about Bloomington a few days earlier. Larvæ of this larger form were found in wheat fields in southern Illinois in May, and the adults were observed in the same section of country in late May and early June by Prof. H. Garman, at that time assistant to Dr. S. A. Forbes.[b] Doctor Riley de-

[a] Prairie Farmer, July 8, 1882.

[b] Fourteenth Rep. State Ent. Ill., pp. 34-37, 1885.

scribed this larger form as a new species, giving it the name *grande*.[a] During the years 1884 and 1885, however, the senior author reared Riley's *Isosoma tritici* from straws in which only his *I. grande* had oviposited and his *I. grande* from plants to which only *I. tritici* had access. As this last name had been applied by Doctor Fitch many years earlier to another insect, the jointworm, the name *grande* must necessarily be given to both forms.

FIG. 7.—*Isosoma grande:* Pupa of summer form in young wheat. (Original.)

BUREAU NOTES AND OBSERVATIONS BY ASSISTANTS.

Strangely enough, one of the earliest reports of this species came from Mr. J. A. Starner, Dayton, Columbia County, Wash. Infested straws containing a few larvæ, but mostly pupæ, were received September 16, 1882, showing that even at that early date it was sufficiently abundant to attract the attention of farmers. Mr. D. W. Coquillett found it at Anaheim and Atwater, Cal., in 1885, while Mr. Albert Koebele found it during the same year at Folsom, Cal. It was also sent to the Department by Mr. J. F. Donkin, from Grayson, Cal., during the same year. In 1885 Prof. F. H. Snow reported it as doing serious injury in McPherson, Morris, Osborne, Ottawa, and Saline counties, Kans., and mentioned it as a new pest,[b] and in 1891 it was prevalent in central and western Kansas.[c] In 1886 Mr. Coquillett found it at Los Angeles, Cal. During August, 1890, infested straws from Washington State were received at the Department from Moses Bull, Pullman; J. W. Jessup, Rosalia; G. W. Dunn, Tekoa; and Milton Evans, Walla Walla.

[a] Bul. Brooklyn Ent. Soc., 1884, pp. 11-12.
[b] Monthly Rep. Kans. Bd. Agr., June, 1885.
[c] Loc. cit., Feb., 1892.

Although there were no reports of damage in the spring, injury was sufficiently marked to attract the attention of farmers, and from these one frequently hears, even up to the present time, descriptions and reminiscences of what seems to have been the first serious outbreak of the pest in the United States.

The senior author found the species abundant but not destructive at Princeton, Ind., in 1887 and again in 1902. June 27, 1893, infested straws were sent to the Department of Agriculture by Mr. E. J. Woodville, Indiantown, Va. In 1905 the junior author found the species infesting growing wheat about Conway, Ark., April 7, the larvæ being apparently full grown; and at Petty, Tex., April 14, he found larvæ and pupæ present in great numbers, in some cases 50 per cent of the young wheat plants being infested. He also found half-grown larvæ at Concordia, Kans., April 21. During the same year the senior author found larvæ in young wheat at Lexington, N. C., April 12; and at Statesville, N. C., on the following day, he found not only larvæ in the young plants, but females of the spring form in the act of ovipositing. At Charlotte, N. C., April 14, larvæ and pupæ were found abundantly in the young wheat. On the 18th of the same month young larvæ were found in young wheat plants at Dublin, Va. Mr. W. J. Phillips found the species quite numerous in young wheat plants at Nashville, Tenn., April 20, and studied the oviposition of both forms at Richmond, Ind., from May 26 to June 27. June 16 the Bureau received infested straws from Mr. H. W. Joy, Hays, Kans. On May 24 of the following year, Mr. Phillips found the species abundant at Geneva, Ind., where the females of the summer form were just beginning to emerge from the young wheat; and the senior author observed it again at Charlotte, N. C., May 9, with indications that it had done considerable injury to young wheat. Mr. Phillips observed it during 1907 at Kingfisher, Okla., and at Beloit, Kans., on April 15; at Lenora, Kans., May 20; and at Kearney, Nebr., May 24. In all cases it was more or less abundant. June 1 of the same year Mr. C. N. Ainslie found adults of the spring form at Wellington, Kans.; from April 30 to May 7 he found the adult females of this form abroad in the fields at Sterling, Kans.; and on May 26 he found them ovipositing in wheat at Hays, Kans., and other points

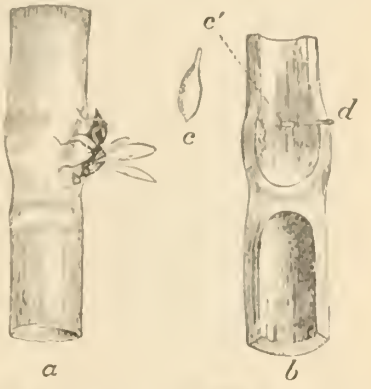

FIG. 5.—Method of oviposition of female of summer form of *Isosoma grande*: *a*, Female inserting her eggs; *b*, section of wheat stem showing egg and ovipositor; *c*, egg, greatly magnified; *c'*, egg in position in pith of wheat stem; *d* ovipositor. (*a*, After Riley; *b*, original.)

farther west. He found them ovipositing in durum wheat at Oakley, Kans., June 3, and on the following day also in durum wheat at Colby, Kans. Again, June 8, he found them abroad in wheat fields at Manhattan, Kans. Females of the summer form were observed by Mr. E. O. G. Kelly ovipositing at Caldwell, Kans., May 14, 1908.

May 26 to 28, 1908, Mr. Ainslie found both sexes, the females ovipositing, near Chambersburg, Pa. This is the farthest east that we have any record of the existence of the species, the most eastern point of occurrence previously known being at Andover, in extreme northeastern Ohio, where the senior author found the larvæ in wheat straw, August, 1904.

As will be observed from the foregoing, the adult female emerges early in spring and deposits her eggs in the young wheat plants before the latter have made much growth. By the time wheat is beginning to show the heads within the enfolding sheath leaves, adults of the

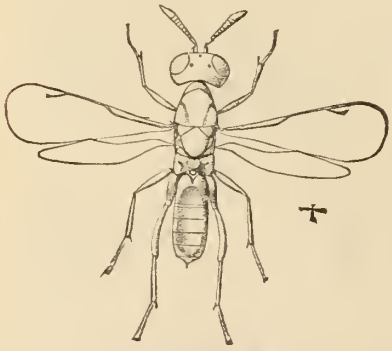

FIG. 9.—*Eupelmus allynii:* Male, much enlarged. (From Riley.)

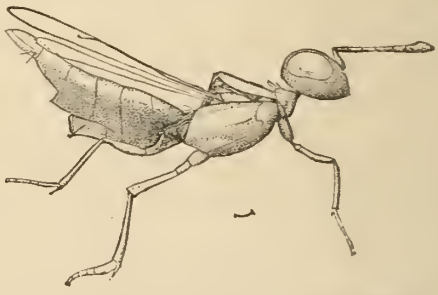

FIG. 10.—*Eupelmus allynii:* Female, much enlarged. (From Riley.)

second generation are abroad and depositing in the upper stems; the larvæ from these pass the winter as pupæ and emerge as adults early the following spring, exact dates of course varying with the latitude and other influences.

NATURAL ENEMIES.

Probably the most efficient enemy of this species is a small, slender, four-winged fly (figs. 9, 10), with a somewhat brilliant metallic body and yellow legs. It has a very slight resemblance to an Isosoma, and, indeed, was described by French as *Isosoma allynii*, but it is now known as *Eupelmus allynii*. A somewhat similar insect with metallic body and yellow abdomen, *Semiotellus isosomatis* Riley (fig. 11), is very efficient in destroying the larvæ in the straw. *Homoporus* (*Semiotellus*) *chalcidiphagus* Walsh (fig. 12), and beyond a doubt other chalcidids, are also instrumental in holding it in check. These

parasites are all the more efficient as they are double-brooded, developing in late summer and at once ovipositing in other larvæ.

In 1908, at Wellington, Kans., Mr. E. O. G. Kelly, beginning April 10 with the larvæ in the straw, followed the insect up to June 4, witnessing oviposition in both the spring and summer forms. Through the remainder of June and most of July he was absent, and on his return he was unable to find the larvæ in the straw, although stubble and straws perforated with holes made by the escaping parasites were found everywhere in the fields. On account of the abundance of such evidence in the fields, Mr. Kelly was convinced that the pest had been largely overcome in that locality by *Eupelmus allynii*. At Pratt, Kans., November 17, a few larvæ were found in wheat straws, with indications that parasites had been present to a limited extent, and practically the same situation was found to occur at Sedgwick, Kans., the following day. Quite significant, however, was the fact that in the vicinity of Pratt, on September 16, Mr. T. D. Urbahns found in an

FIG. 11.—*Semiotellus isosomatis*. Parasite of *Isosoma grande*. Greatly enlarged (Original.)

FIG. 12.—*Homoporus chalcidiphagus*. Parasite of *Isosoma grande*. Greatly enlarged (Original.)

old wheat field not a single living Isosoma larva, while 85 per cent of the straws gave unmistakable evidence by the holes in them that these larvæ had been present, but were destroyed by parasites.

Quite in accord with this it will be remarked that the junior author, in his discussion of the outbreak of the pest in Washington State, in 1908, does not mention parasites at all—not because he overlooked the matter, but because he reared only a single individual parasite, probably *Semiotellus isosomatis* Riley, and there was no evidence of the presence of parasites in any numbers in the section of country visited by him. This will perhaps throw some light upon the prime causes of this outbreak. Besides, it opened the way for an introduction into Washington State of the parasites affecting the pest in the East. It is as yet too soon, however, to expect definite results from these introductions.

In Indiana and the Middle West when the wheat is harvested the straw is frequently, and, in fact, almost invariably, cut off between

joints, thus leaving the larvæ, if there are such in the straws at that point, exposed to attack from predaceous insects. The larvæ of a small, slender, black and yellow carabid beetle (*Leptotrachelus dorsalis* Fab.) crawls up the stalks, descends into the stubble, and devours the Isosoma larvæ, but unfortunately its taste is such that it does not confine itself strictly to Isosoma but devours parasite as well as host. The mite *Pediculoides* (*Heteropus*) *ventricosus* (fig. 13) is also an enemy, gaining access to the larvæ precisely as do the beetle larvæ previously mentioned.

PREVENTIVE MEASURES.

There are no remedial measures, since it is impossible to alleviate or influence in any way the effect of larvæ in the infested wheat plants. As it is the larger and more vigorous plants that the females select for egg-laying purposes, no amount of enriching the soil will affect the numbers of the pest or lessen their influence. Preventive measures are, however, simple, practicable, and effective. Indeed, the wheat-straw worm is one of the very easiest of all insects to control. The diminutive size of the female that emerges in early spring renders extended migrations fatal, since during that period, when the weather is, of all seasons, the most erratic and liable to sudden and extreme changes, it tries to avoid the frequent storms by seeking protection on the underside of the leaves of the growing plants. But, most fortunate of all for the farmer, large numbers, if not indeed much the greater proportion, of these females have no wings and can only make their way from place to place by crawling.

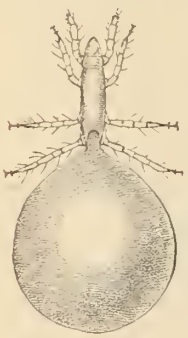

FIG. 13.—*Pediculoides ventricosus* Newp., a mite which destroys the larva. Much enlarged. (After Marlatt.)

The advantage of all of this to the farmer is shown by the fact that, where the preceding crop has been other than wheat, the injury to the young wheat plants in spring is confined to the margins, and especially where such margins border on other fields that have been devoted to wheat for a number of consecutive years. Mr. Reeves, as will be observed further on in this publication, has been able to measure the relative diminution of attack from the borders of the field inward toward the center. Similar observations had previously been made in other sections of the country. One of the earliest notes made on this species by the senior author was in June, 1884, in a field of wheat sown the previous autumn, among corn, the land bordering to the south on a stubble field. The following spring there were many wheat plants injured along the south margin of the field, but none could be found along the northern border. With the appearance of

the second generation, composed of large, vigorous females with well developed wings, the diffusion would become comparatively general, and, therefore, the second year, if the field were to be continued in wheat, would find the infestation more nearly uniform throughout.

It is significant, too, that the pest becomes much more destructive the longer wheat is grown continuously on the same ground. As early as 1882 Prof. G. H. French observed that while 93 per cent of the straws were infested in a field where the same grain had been grown the year before, in a field where clover had been grown the previous year only about 5 per cent of the straws were infested. At Petty, Tex., April 14, 1905, the junior author found a field of wheat that had been in this grain for two consecutive years very seriously injured. There were spots several yards square where the ground was bare, and surrounding these were areas where half of the living plants were infested. At Sawyer, Kans., in an old field, Mr. Urbahns found that 85 per cent of the straws gave unmistakable evidence of having been infested. All of this points conclusively to the efficiency of a rotation of crops that will eliminate the growing of wheat two years in succession on the same land. Where for any reason this can not be done, the measure next in efficiency will be the burning of the stubble and outstanding straw during the fall or winter.

RELATIONS OF THE WHEAT STRAWWORM TO WHEAT PRODUCTION IN THE NORTHWEST

By Geo. I. Reeves.

The wheat strawworm, by reason of its relation to both the climate and the farm methods of the most productive portion of the Pacific Northwest, is capable of great injury to wheat growers. Though its greatest inroads are made upon spring wheat, it is winter and volunteer wheat which render those inroads possible. Its work is of such nature that it passes unobserved, unless an attack of unusual severity causes the farmer to scrutinize his fields more closely than he is accustomed to do. The constant small losses occasioned by this insect and the possible destruction of the crop over considerable areas may be prevented by such measures as every good farmer employs to maintain the fertility of his soil, secure a good seed bed, retain moisture, and eradicate weeds.

The strawworm may be found wherever wheat is grown in the Columbia basin, that great and fertile plain of varying topography and climate which is inclosed by the Okanagan Highlands on the north, the Rocky Mountains on the east, the Blue Mountains on the south, and the Cascade Mountains on the west; but it is not equally destructive over all that territory. The central and western parts of this basin, except in the Goldendale and Horse Heaven districts,

are arid, producing little or no wheat, and a strip east of this, known as the dry-farming region, where the scanty rainfall makes it necessary to summer-fallow the land every second year, is by that means protected from serious injury; but the eastern zone, a strip 200 miles long, included between the dry-farming area and the upper limit of wheat culture at the elevation of 3,000 feet, affords ideal conditions for the production of small grains and also for the propagation of this insect. The climate is characterized by mild winters suitable for the growing of winter wheat—cold, wet spring weather, such as is desirable for all small grains, and hot, dry summers perfectly adapted to the maturing and harvesting of the crop. The soil is such that after more than thirty years of almost continuous production it still yields 30 to 40 bushels of wheat per acre. These conditions encourage the seeding of wheat year after year upon the same ground, and such a practice, together with the presence of winter or late volunteer wheat, supplies the requirements for the unhindered multiplication of the strawworm. Owing to the drought of summer the volunteer wheat usually does not germinate until about the same time as the fall-sown wheat, and the significance of this fact appears when we come to study the insect's life history.

This Isosoma passes the winter in the larval (fig. 1) or pupal (fig. 7) stage and reaches maturity early in April. It gnaws its way out of the stubble in which it has hibernated and deposits its eggs in the heart of the young plants of winter or volunteer wheat (fig. 6), which must be near the place of emergence, since this early generation is largely wingless (fig. 3), and its effective range as measured by the spread into an adjoining field is not much more than 12 feet. The food plants of the early generation may be supplied by winter wheat or by volunteer wheat not too far advanced to attract the insect. The oviposition is finished before any spring wheat is up, so that that crop suffers no attack from the first generation. The winter and volunteer wheats lend an essential aid to the perpetuation of the species.

The larva (fig. 5), when it hatches from the egg, is surrounded by the most delicate tissues of the plant and feeds upon them, destroying the young head and thus excavating a residence to accommodate its rapidly increasing size. The outer, tougher layers, which it does not attack, gradually become fleshy, stiff, and brittle, forming a hollow, bulblike swelling at the base of the plant. This enlargement is discernible from the outside of the infested plant, and its presence may be verified by squeezing the crown of the plant between the fingers, whereupon the bulb at first firmly resists pressure and then breaks open, disclosing the larva. The infested plant suffers a change in external form, which causes it to resemble wheat

injured by the Hessian fly and by Meromyza, but it may usually be distinguished from the former by the curly and slightly fleshy form of the blades; from the latter by the absence of the brown, threadlike central shoot, as well as the form of the blades; and from both by the presence of the crisp bulb at the crown. The lower blades are broad, dark bluish green, curly, and slightly fleshy, because they arise between the root and the point of injury and thus receive the sap that is being diverted by the larva from the main growing point of the plant. The plant, when attacked thus early at the heart, remains low, does not produce any head, and perishes when the lower blades of the plants naturally die, about the middle of June. At about the same time the adults of the second generation (fig. 4) begin to emerge from these plants and deposit eggs upon the wheat. These insects, as were those of the first generation, are nearly all females, and they also reproduce without the assistance of males, but they differ from the earlier form in being larger and in possessing wings, which enable them to attack fields at a distance from their origin. They prefer the younger plants, and as the spring wheat is small at this time, while the winter wheat is old and tough, the summer attack is concentrated upon spring wheat, if there be any in the vicinity. They attack it in much the same way that the spring generation employs upon the young winter wheat, and with the same result; the smaller plants simulate a luxuriant growth, but remain short and soon die; the larger ones may produce heads, a few inches above ground, but such heads contain no kernels. Thirty acres of spring wheat near Colfax, Wash., were completely ruined in this manner in the summer of 1907.

Since spring wheat is not so extensively grown as formerly in this region, the summer adults are often compelled to oviposit in winter wheat, and in those cases the plant is less severely injured, because it is old and tough; but the larva of the insect and the resulting adult take the same form and size whether they develop in the tender spring wheat or in the more mature winter wheat. The succulence of the former does not cause an increase in the size of the larvæ which feed upon it, nor does it produce a larger proportion of winged individuals among the adults. On the contrary, it seems that austere and unfavorable circumstances tend to increase the number of winged adults, as a large percentage of those reared from stubble collected at Goldendale, St. Germain, and Waterville, Wash., in the arid district, have wings. The egg is placed in a tender joint near the head (fig. 8) and the larva hatches and gnaws the inner surface of the stalk, too late to prevent the formation of the head, but early enough to shorten it and hinder the filling of the kernels. To ascertain the amount of this injury 1,452 heads taken from an apparently unin-

jured field of winter wheat near Pullman, Wash., were dried and weighed. Thirty-nine per cent of these were afterwards found to have grown upon stems damaged by the strawworm, and the average weight of the heads from these damaged stems was 22 per cent below the average of healthy heads, although no difference in size was noticeable until the heads were placed side by side, when it was found that most of the larger heads were those from uninjured plants, while most of the shorter ones were from infested plants. Between heads of the same size there was a difference of 7 per cent, which could not be detected except by weighing.

Both the work of the spring brood in fall wheat and that of the summer brood in spring and winter wheat are so carried on that the owner does not know of his loss unless it amounts to a very large percentage of the crop, and even then he may attribute it to some other cause. The presence of a large number of unusually rank and apparently sturdy plants among the winter wheat does not seem alarming, but the reverse; and there is no other indication of work of the spring brood. Later, when these infested plants begin to die they are concealed by the yellowing blades of the healthy plants, so that even the trained entomologist can hardly find them. The same is true of the spring wheat which is attacked by the summer brood, while winter wheat plants attacked by the summer brood are, as we have just shown, so little altered in appearance that the presence of the insect can be detected only by weighing the heads or splitting the stems to look within for the larvæ.

Many of the larvæ remain in the stubble if the grain is cut with a harvester, and most of them if it is cut with a header. They begin to pupate during the latter half of July, but many remain in the larval condition until May of the following year.

The life history just related shows that strawworm injury is induced by growing crops of winter wheat repeatedly upon the same ground; by leaving volunteer plants among the spring wheat; by allowing summer fallow to grow foul with volunteer wheat, even at a distance from wheat fields; and by growing spring wheat near winter wheat. All of these cases occur at times in the wheat country which we are considering. The essential conditions in each of these cases are, first, the presence of infested stubble, plowed or unplowed, to furnish the early adults; second, a growth of winter or volunteer wheat early in the spring to receive the eggs of the first generation; third, a crop of winter or, preferably, spring wheat to receive the eggs of the second brood. The remedy lies in avoiding these conditions by rotation of crops, clean early summer fallowing, and the abandonment of spring-wheat culture. Fall plowing of the stubble does not prevent the insects from coming out and attacking wheat in the

spring. Burning the stubble is impracticable, because the joints which contain the larvæ remain sappy during the fall and will not burn. Rotation, to be effective, must be planned with reference to the work of the insect, since two adjoining fields which are in wheat in alternate years have between them a strip 2 rods wide which always furnishes ideal conditions for its spread. The stubble in one field always furnishes insects to attack the growing wheat in the other, and while the damage done by the wingless first generation is limited to the 1-rod strip next the fence, the winged second generation spreads at will through the field.

There is no reason why an insect, so readily held in check merely by careful farm methods, should cause constant loss and an occasional menace to the wheat country of the Northwest, but there is no doubt that it does so.

Approved:

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